Technical Meeting of the Institution

held at

The Institution of Electrical Engineers

Wednesday, February 12th, 1958

The minutes of the Technical Meeting held in London on January 15th, 1958 were read and approved.

The **President** introduced to the meeting Mr. J. H. Fensom (Student) who was present for the first time since his election to membership.

The President (Mr. A. W. WOODBRIDGE) in the chair

The **President** said that he was going to take quite an unprecedented step in introducing Mr. Currey and his paper on " The B.T.C. Automatic Train Control System." He wanted to warn people present that those meetings were normally private meetings and the views expressed by members were entirely their own views. They were also subject to publication in the Institution's Proceedings in due course and no publication of the comments was to be made before the Institution's Proceedings were published. There might be members of the Press present and the President asked them to interpret his comments in a proper manner. He then called upon Mr. Currey to read his paper.

The B.T.C. Automatic Train Control System

By JOHN H. CURREY (Member)

Introduction

In introducing a paper on a new subject or one which has not been discussed for some time it is customary to deal with the historical facts leading up to the present but in view of the necessity to compress the whole development period and a description of the equipment and its operation into one paper of readable length it is proposed to omit all references to existing systems and to start straight away with the decision of the Railway Executive in 1951 to set up a Committee to develop a system of Automatic Train Control with the following remit :—

(1) Link between track and vehicle to be inductive.

(2) Vehicle equipment to be ex G.W.R. modified to work with an inductive link to the track.

(3) No visual indication to be provided.

Although the remit has never been altered, items 2 and 3 were tacitly dropped at an early stage in development.

Various decisions were made as to the methods of control and operation to be adopted after consideration of the ex G.W.R. and ex. L.M.S. "Hudd" systems and initial trials were carried out under the following conditions.

Track

Track magnets of the Hudd type, but spaced at 5-ft. centres to be fixed approximately 200 yards on the approach side of all distant signals.

No indication to be given at combined stop and distant signals when the stop signal was *on*.

Locomotive

Receiver of Hudd pattern modified to operate electric contacts, ex G.W.R. syren for caution and 4-second bell for clear. Brake to be applied via the syren without balanced brake valve.

For the purpose of the trials, the down main between New Barnet and Huntingdon was fitted with track inductors of the Hudd pattern obtained from a stock in

Scotland originally intended for the Glasgow Queen Street-Edinburgh line, two experimental types of "suppression" permanent inductors were fitted to combined stop and distant signals. A number of express locomotives were fitted with the modified Hudd receivers and G.W.R. cab apparatus. Preliminary tests soon made it clear that with the standard vacuum ejectors it was not possible to obtain a loud syren and effective brake at the same time. A certain minimum pressure drop is necessary to operate the syren and this pressure drop prevented sufficient air from entering the train pipe to overcome the ejector. This resulted in the decision to fit a balanced brake valve as used with the Hudd system.

The suppressor type permanent inductors were by no means satisfactory and it was decided to disconnect the suppressor coil and use them as ordinary permanent inductors pending the outcome of discussions as to whether or no a caution indication should be given to the driver at a combined stop and distant signal showing *stop*. These suppressor coils were never re-connected.

Trials with this apparatus convinced the designers that a compromise such as this could never be wholly satisfactory and it seemed to them undesirable to equip the whole of British Railways for many years to come with a compromise instead of a system specially designed for the purpose and early in 1952 they sketched out their ideas and designed and started to build in Derby loco works toolroom the first specialised piece of equipment, what is now generally called the driver's control unit.

A week or two before this first unit was complete, the disastrous Harrow accident occurred and public interest was in A.T.C. at its height. This unit was fitted, together with a hook-up relay unit, on engine No. 60130, an A1 Class named "Kestrel" and had its first run one morning. The author arrived at King's Cross after lunch to travel on the footplate and observe its behaviour for its second run and was flabbergasted to find most of London's Press photographers on the platform. By the greatest of good fortune, the apparatus on both its first and second runs behaved perfectly but the sequel is an example of how good can come out of evil. The designers were convinced from experience with the Hudd system that a visual indicator was of the greatest value to a driver and had incorporated one in this first driver's control unit despite the remit. When the Press photographs appeared in all the morning papers, the one part which stood out clearly and so received universal mention was the indicator and it was obviously impossible to explain to the Press that it should not have been there and would not be fitted in the future. The author feels entitled to claim that subsequent experience, has convinced responsible authority that the indicator is a valuable adjunct to the audible warnings.

Following successful runs with this single unit the order was given that 54 locomotives should be similarly fitted and despite protests from the designers that this driver's control unit was only one component and that the remainder of the equipment was merely a-hook up, the order was enforced but while the apparatus was being constructed, numerous defects were discovered in the driver's control unit itself and many modifications were made, some units being modified at least five times before they were fitted on a locomotive. During the following twelve months the A.T.C. design staff were kept so busy correcting faults in the temporary equipment that virtually no further design work was undertaken but having got this, apparently, into some semblance of reliability the whole of the remainder of the equipment was redesigned and built. The building of this new material naturally took some months and during this period the temporary equipment broke down completely and practically all the locomotives had to be stripped of their A.T.C. apparatus.

The introduction of the new and specially designed apparatus opened a second phase in the development of this A.T.C. system and although a large number of minor modifications had to be made, either to cure weaknesses in design or to improve the overall reliability of the system, in their essentials the first 200 sets of apparatus now being produced, are identical with these first sets of apparatus specifically designed as a complete system with no suggestion of compromise. British Railways might never again have the opportunity to fit an entirely new system of Automatic Train Control so that the system to be adopted now must use, wherever applicable, the latest knowledge of materials and manufacturing processes if it was to stand the test of time.

Following the design of the locomotive equipment, attention turned to the track. The Hudd type inductors were of a longitudinal type so that a locomotive receiver passed over both magnetic poles of each inductor in succession. It was therefore possible after a North pole on a permanent inductor approaching an outer distant signal at caution to leave the horn blowing and the brakes applied and then pass over the South pole of the permanent inductor at the inner distant signal. This North/South operation corresponded to a clear distant signal and a bell would be superimposed on the horn. To prevent this it was decided to redesign the inductors with their magnets in a vertical plane so that an engine receiver passed over one pole only, this being made possible by the improvements in permanent magnetic materials which had taken place since the Hudd magnets were designed. The body chiefly responsible for the redesign of the permanent magnet inductors was the Permanent Magnet Association of Sheffield and that Association did its work so well that the volume of magnetic material in the present inductors is less than one-fifth of that in the Hudd type and yet is appreciably more powerful; the Hudd type operating through a 4-in. and the present pattern through a 5-in. air gap. When these inductors were being redesigned an attempt was made to reduce the centre to centre distance of the two inductors to approximately 2-ft. 6-in. so that they could be fixed across adjoining sleeper spaces. The Permanent Magnet Association found that an extra £1 worth of magnetic material would then be required to overcome the flux lost through the iron circuit of the adjoining electro inductor but that this could be avoided if the polarities were reversed as the flux lost through the electro inductor was then neutralised by the strength and direction of the earth's magnetic field in this country. As a result the operating polarities of the system are reversed as compared with the Hudd system and the two inductors are closed up together.

Fig. 1 Track inductors at Hatfield

Track Equipment (fig. 1)

The track equipment consists of three units, permanent magnet inductor, electro magnet inductor and protecting steel ramp fixed in the centre of the four-foot approximately 200 yards on the approach side of a distant signal. As stated previously, the two inductors are fitted across adjoining sleeper spaces and the sloping steel ramp covers two sleepers spaces in the approach side. The permanent inductor is passed first in the normal direction of travel and serves to trip the engine apparatus though a 1 second delay is given to allow a slow moving train to reach the electro inductor and sense whether it is energised or not. The electro inductor is energised when the distant signal arm or colour light shows the clear position. This 1 second delay covers train speeds down to approximately $1\frac{3}{4}$ m.p.h. Below that speed the engine equipment will give a caution warning even though the signal is showing clear. The permanent inductor consists of a vertical magnet of Alcomax II 5 inches high with a cross section of approximately 9 square inches and is fitted with steel spreader plates 10 inches long by 5 inches wide at top and bottom, forming a magnetic structure like an H on its side. This unit is mounted in an aluminium alloy casing of a size to span one sleeper spacing. The whole unit is above sleeper level and the top of the inductor, packed up if necessary, should be at new rail level.

The electro inductor consists of a similarly shaped magnetic structure though the centre core is of a Swedish iron type and is considerably longer than the magnet in the permanent inductor. To compensate for this and achieve a similar flux curve to that of the permanent inductor, the two ends of the lower spreader plate are bent upwards.

There are two windings on the core which are brought out to terminals in a box bolted to the side of the inductor and links provided to enable the coils to be connected in series or parallel for 24 or 12 volt operation. The power consumption is 9 watts. Due to the size of coil necessary to give the magnetic flux required with economy of current, this unit goes down into the ballast though the top of the casing is fixed at new rail level.

Great care has had to be taken to keep the interior of this unit dry and free from the effects of vibration caused by the passage of heavy high speed trains. A rigid specification for the impregnation of the coil is required in case of any damp entering the case and the two halves of the case securely jointed. The coil connections to the terminal box are also hermetically sealed. However, until more experience can be gained, which must spread over a matter of years, the standard inductors will have their cases filled with petrolatum. Ten dry inductors, acting as guinea pigs have been fitted in the track for some time, to ascertain if the petrolatum is necessary.

The terminal box entry for the supply cable is fitted with a sealing gland designed for the use of the new track cable to B.R. Specification 792. No common decision as to how track cable should be brought from the lineside to the track seems to have been reached. The author favours a rubber hose protection over the cable between track equipment and surface boxing if this is used or to a hollow concrete marker block through the centre of which buried cable can be led to the surface. Possibly the increasing use of track cleaning and tamping machinery by the Civil Engineer may enforce the use of a detachable coupling on track equipment to enable the cable to be quickly moved out of the way of such machinery and equally quickly rejoined. If this proves desirable, a coupling of the design used for the engine A.T.C. receiver cable should prove satisfactory.

As the electro inductor is fixed to the sleepers but reaches below ballast level it is desirable to surround it with a box to prevent excess ballast getting under the casing and forcing it off the sleepers.

Considerable difficulty has been experienced in designing the inductors to enable them to be fitted both to timber sleepers and the various designs of concrete sleeper with the differing heights of rail level above centre of sleeper level. At the time of writing, the final design has not yet been approved by the Chief Civil Engineer but the following features have been found essential. Three hole fixing, flexible rubber mountings in the fixing holes and special fixing hole centres to enable one pattern of cored fixing holes in concrete sleepers to carry both ends of each inductor and the ramp fixing lugs. Even so various packings will be necessary to cover all the designs of sleeper, base plate and rail.

The operating member of the engine receiver consists of a moving permanent magnet which, consequently, requires a certain time for its operation and the speed of operation will increase as the magnetic force acting on it is increased. It is essential that the receiver shall have operated due to the permanent inductor before it enters the field of the electro inductor and it was found that the speed of operation at minimum strength was too slow for this to be achieved at maximum train speeds. It was therefore necessary to design the inductors to have a magnetic flux considerably in excess of that required to operate a stationary receiver. Fig. 2 shows the minimum specified flux density along a line 5 inches above the top of the inductor and also the curves actually produced from the magnetic structure to embrace these minimum requirements. The flux density in air to operate a stationary standard receiver is approximately 17 Gauss so that it will be seen that there is a considerable margin to cover operation at higher speeds. The maximum speed possible cannot be directly obtained by running locomotives on the track but oscillographs taken at high speeds indicate that the maximum may be in excess of 150 m.p.h. It is hoped to obtain data from which a more accurate assessment may be made in the not too distant future.

The supply to the electro inductors may be obtained in the various ways familiar to signal engineers, viz. rectified A.C., trickle charged secondary cells, primary cells with approach track circuit or, with some colour light systems, the signal battery itself may be used avoiding the provision of a special location for the inductor supply and control provided that, under normal conditions, 12 volts is obtainable at the inductor terminals. An interesting and economical arrangement where power is not available is to trickle charge NIFE cells from primary cells. If a sufficiently high charging resistance is included, this arrangement avoids the use of an approach track circuit, provided, of course that the signal box controlling the inductor is continuously open.

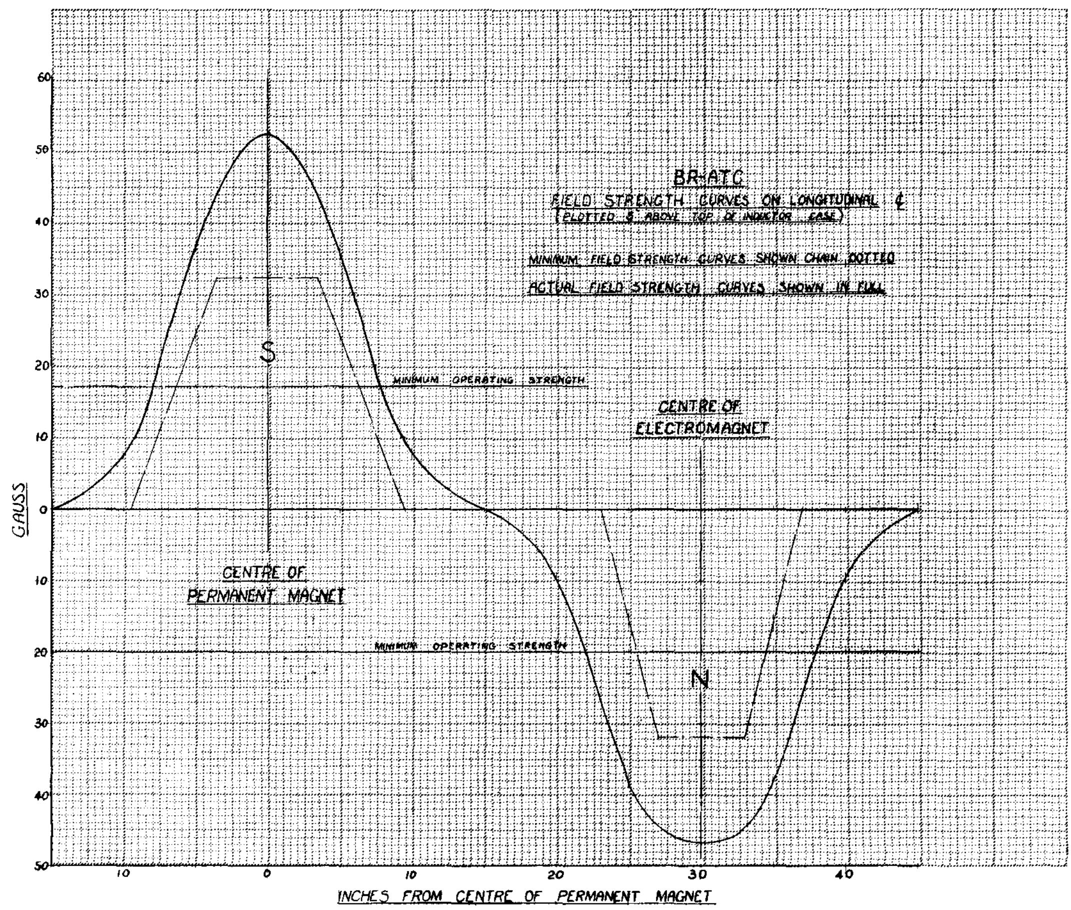

Fig. 2

With wire operated semaphore distant signals, the inductor relay should be controlled from a signal box battery through an *off* contact on the distant signal lever and also through an arm contact on the signal made at 25° to 30°. The inductor relay should be proved in the de-energised position by including a back contact in the distant signal *on* side repeater circuit. It is highly desirable that full block controls shall be associated with the provision of A.T.C.

When semaphore distant signals are motor worked it seems unnecessary to run special A.T.C. control wires from the signal box ; the motor relay can control the inductor relay through an arm contact on the signal. Inductor relay proving and block controls remain as for wire worked signals.

For colour light signals, the D.R. can control the inductor relay through a contact of a DECR. If the signal is operated from a signal box and block working is in force, the proving and controls remain as for a motor worked semaphore distant signal but with automatic signals the inductor relay can be proved in one of the various ways adopted for train stop proving.

It will be apparent that where a line is signalled for two way working, it is undesirable for a train travelling in, say, the up direction to receive A.T.C. indications intended for trains in the opposite direction. To achieve this means have to be found to prevent the unrequired permanent inductors from tripping the locomotive gear. The original suppressor inductor comes in useful here and designs are being developed on these lines at present. The permanent magnets have such a powerful field that a considerable wattage is necessary to divert it. It looks at present as if this wattage may be around 40 and consequently a power supply is almost an essential at suppressor type permanent inductor locations.

Steam Locomotive Equipment

With few exceptions today in this country braked steam hauled stock is vacuum fitted and consequently the A.T.C. system has been designed for vacuum fitted locomotives. The braking action is applied to the vacuum train pipe, any other type of brake in use on the locomotive being operated through some type of combining valve which probably exists already.

The equipment on the locomotive consists of the following items as shown diarammatically on fig. 3. Receiver, receiver junction box, relay unit fitted into relay junction box which also carries a vacuum operated switch, driver's control unit incorporating electro-pneumatic valve, indicator and re-setting handle, vacuum operated horn, electric bell, 12 volt 32 A.H. NIFE battery, fuse box, brake valve, emergency isolating cock, non-return valve, main vacuum reservoir and timing reservoir.

The receiver consists of a small permanent magnet pivoted between soft iron laminated pole pieces. These pole pieces are in magnetic contact with iron collector plates, a 5-in. diameter lower plate and a top plate 16-in. × 10-in. The permanent magnet armature carries fixed stop pins and a flexible beryllium copper strip carrying contacts at either end. The complete operating unit including the pole pieces is located in an aluminium bronze frame which carries adjustable stops for setting the armature travel and adjustable contacts which connect with the armature flexible strip. A coil is wound round the lower pole piece to magnetise this and so reset the receiver armature when required. Five wires, i.e., armature, normal contact, reverse contact and re-set coil, are taken through a sealing gland in the top collector plate to a 5 way socket. The whole of the operating unit including the lower collector plate is enclosed in a non-magnetic cast iron pot which is hermetically sealed to the top collector plate.

The receiver is fixed below the locomotive with the bottom of the pot 5 inches above rail level (fig. 4). Rubber mountings are used to reduce shock.

In order that the receiver may be quickly changed by a locomotive fitter a length of 5 core flexible cable, protected by rubber hose and fitted with a sealed plug at either end, is plugged into the socket on the receiver and also into the socket of a junction box fixed close to the receiver. The plugs and sockets have had to be specially designed to keep out water against the pressure achieved by a locomotive travelling at speeds up to 100 m.p.h. and also to maintain efficient electrical contact under the violent oscillations to which a bogie carried receiver may be submitted. Spring loaded plungers make contact with fixed studs and the rims of the cable plugs

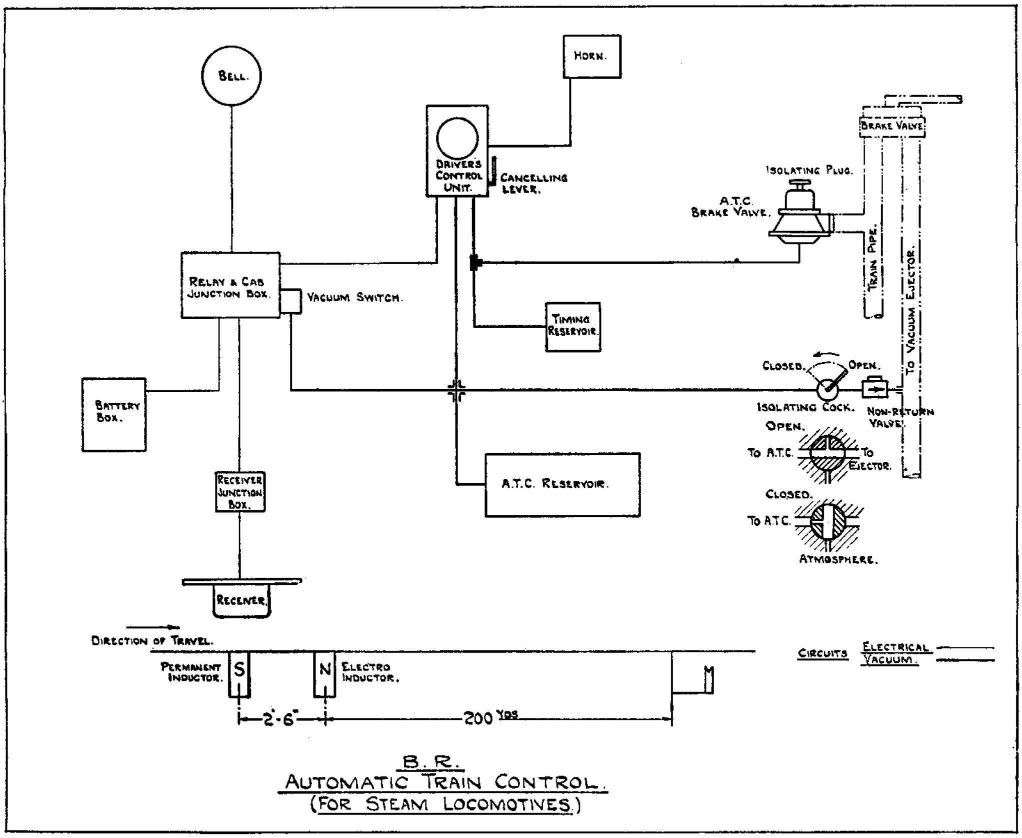

Fig. 3

are screwed by heavy retaining rings into pressure contact with solid rubber to form an hermetic seal. The cable sheath emerging from the plugs passes through a compression type rubber gland. If the receiver is mounted on a bogie frame, the junction box is on the engine frame and the flexible cable allows for 10 inches relative movement between receiver and junction box on either side of the normal position. From terminals in the junction box through a compression gland a length of 5 core cable is taken in conduit along the engine frame to terminals in the relay junction box. To simplify wiring by relatively unskilled men, crimped tags are universally used on all engine wiring.

In order to avoid corrosion in the threads of screwed conduit, lengths of rubber hose with jubilee clips are used to connect the various lengths of conduit and to connect the conduit to apparatus. This also allows a degree of flexibility-without straining screwed joints.

All locomotive wiring is brought in to the relay junction box and those wires which have to enter the relay box are taken from these terminals to a row of fixed studs. The relay unit itself is cast integrally with the lid of the junction box and carries a row of spring plungers which connect with studs when the lid is bolted in position. In the relay unit a flexibly mounted tray carries the relays, condensers, etc., required for translating the receiver signals into audible and visual indications and effect braking. When the lid is bolted down, the relay unit is hermetically sealed against the action of the fireman's washing-down steam hose.

Bolted to the side of the junction box is a vacuum operated switch which acts as a battery economiser. When the small ejector is shut off, the vacuum in the main

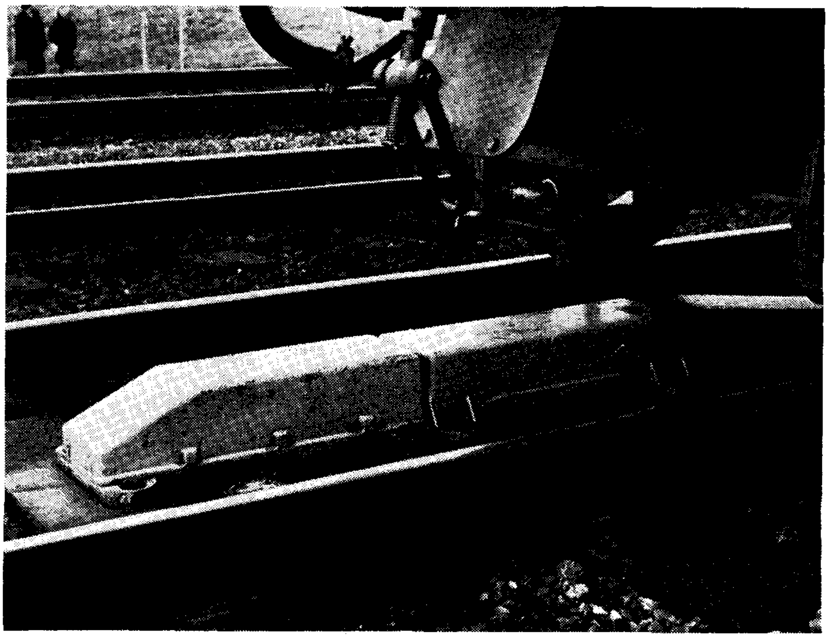

Fig. 4 Engine receiver passing over inductors

reservoir slowly leaks away until at about 2 inches, the switch opens and isolates the battery.

The driver's control unit houses a solenoid operated semi-rotary vacuum valve so designed that although the armature will hold up at 12 volts, it will not pick up even at 100 volts, it has to be picked up mechanically by the depression of the re-setting handle. The solenoid, whose resistance is 250 ohms, is normally energised and with the armature in this position, the valve ports are so aligned that the vacuum horn is connected to atmosphere, and the brake valve to the main vacuum reservoir. When the solenoid is de-energised the valve ports are reversed, the horn is connected to the vacuum reservoir and the brake valve to atmosphere through a small bleed hole. Coupled to the re-setting handle and interposed between the semi-rotary valve and the valve block is another semi-rotary disc with ports so arranged that if the re-setting handle is pulled down, air is admitted to the brake valve. The object of this valve disc, or anti-forestall valve, is to prevent a driver attempting to cut out the A.T.C. by tying down the re-setting handle.

The indicator is of the permanent magnet rotary armature pattern carrying a circular flag painted in alternate black and yellow spokes. In front of the flag is a black mask with cut-out spokes, and flag and mask are so disposed that in one position of the armature the black spokes of the flag are visible through the open spokes of the black mask and in the other position of the armature the yellow spokes are visible between the black spokes of the mask (fig. 5).

A contact drum mounted on the re-set handle spindle is used for resetting the receiver and relay unit when required after a caution signal. The solenoid valve, valve block and resetting handle spindle with contact assembly are mounted on a single chassis so that adjustments may be carried out in servicing shops before the equipment is fixed in its casing. This chassis also carries a 6 way socket. When the unit is closed up, the socket is accessible through the door and a 6 way plug bolts into position on the door. A short length of stainless steel flexible tubing connects the plug to conduit to carry a 6 core cable to the relay junction box. Stainless steel is used here as the driver's control unit is usually mounted on the boiler front with the re-setting handle within easy reach of the driver and the indicator facing towards him (fig. 6).

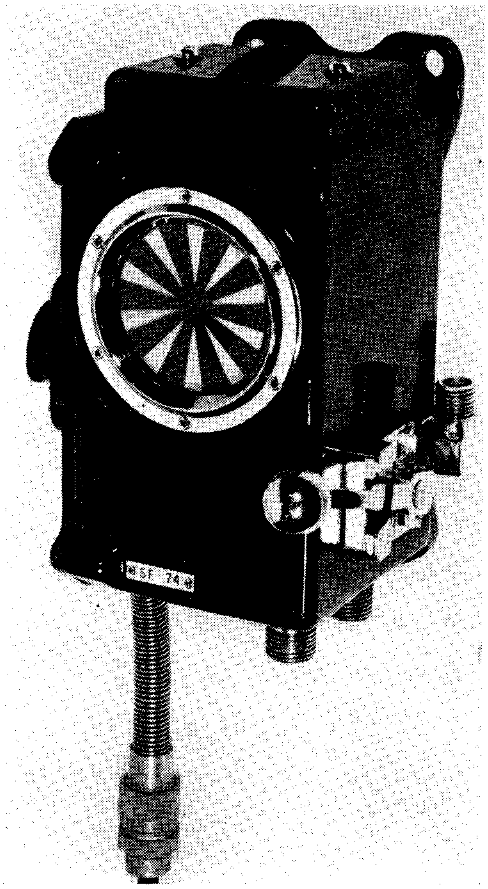

Fig. 5

Driver's control unit

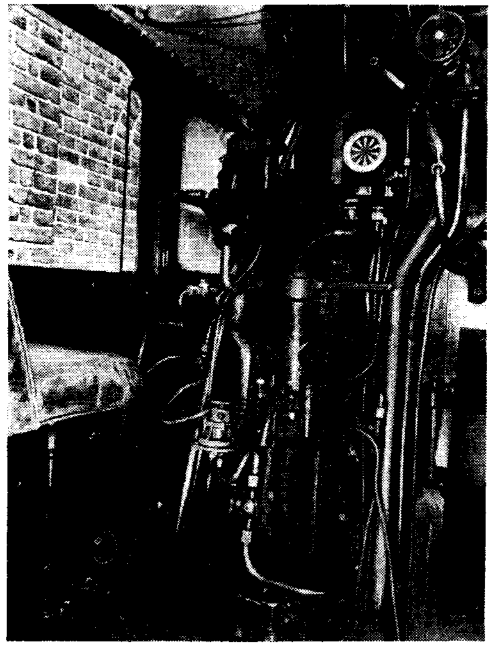

Fig. 6

Cab arrangement Class A4 Locomotive "Sir Nigel Gresley"

The bell has to be very powerful owing to the high level of noise in a steam locomotive cab. The movement is of the thruster pattern, the hammer shaft guide in the bell casing being sealed against entry of damp and corrosive atmosphere by a flexible rubber seal. The case containing the mechanism is bolted with a rubber seal to an aluminium alloy base plate. A two way socket is mounted on this base plate and wires from it led in a tunnel in the casting into the bell casing. The bell plug is connected to conduit by a short length of flexible tubing.

The battery is housed in a steel compartment, to the side of which is bolted the fuse box. Quick release tags moulded in to cable connect the battery terminals to fuse box terminals and also connect two 5 cell crates in series. The fuses are 3 amp. cartridge type in Slydlock holders. The 32 A.H. battery is changed for charging purposes every 4 or 5 weeks and should be overhauled every 5 years. The date when new or overhauled is indicated by a coloured disc on the crate so that each year all crates of a certain colour should be sent to a depot for overhaul.

The vacuum operated horn is of the diaphragm type having a small capacity chamber behind the diaphragm which is connected to the vacuum supply through a restricting orifice. The chamber is sealed from the atmosphere by a small valve coupled to the centre of the diaphragm. When the chamber is evacuated, the diaphragm is bent inwards by the external atmosphere pressure and this movement lifts the valve off its seat allowing air to enter the chamber. The diaphragm springs back closing the valve and the chamber is evacuated once more. This vibrationary movement of the diaphragm sets up sound waves which are concentrated through a short trumpet.

The brake valve has two chambers separated by a rubber diaphragm, the lower chamber being connected to the vacuum supply through the electro-pneumatic valve in the driver's control unit and also to a small timing reservoir. The upper chamber is in direct connection with the vacuum train pipe. This chamber is isolated from atmosphere by a valve which is coupled to the diaphragm. Under normal conditions the diaphragm is in balance as there is equal vacuum on both sides and the valve is kept closed by a light spring. When the electro pneumatic valve is de-energised, air is admitted to the under-side of the diaphragm through a small orifice and after a second or two the diaphragm is sufficiently unbalanced to lift, taking the valve off its seating. Air rushes through the valve into the upper chamber and the train pipe tending to balance the diaphragm again but air is still entering the lower chamber so that after a few oscillations the diaphragm takes up a position where the rate of drop of vacuum in the train pipe equals the rate of drop of vacuum in the lower chamber. As the rate of drop of vacuum in the lower chamber is controlled by the capacity of the timing reservoir and the size of the air orifice, this is constant and consequently the rate of drop of vacuum in the train pipe is constant, regardless of the length of train up to the maximum capacity of the brake valve Allowing for the longer propagation time of air down a long train it might safely be said that from a light engine up to a 12 coach train, the total time to destroy the vacuum in the train pipe is 13 to 15 seconds with a further 3 or 4 seconds required for trains up to 16 coaches.

The purpose of the non-return valve is to ensure that a supply of vacuum is retained in the main reservoir for sounding the horn if the train pipe vacuum is destroyed by the driver to apply the brakes. It has been specially designed with a view to simple maintenance, the essential parts of the valve being in a replaceable cartridge.

In case of a failure of the A.T.C. system it is necessary to have some means of isolation to allow the train to be driven to some place where it can be taken out of service or repaired. An isolating cock which is normally sealed open with lead seal on binding wire is fitted in the vacuum supply to the main reservoir. On cutting the sealing wire and closing the cock, the vacuum supply is cut off and the main reservoir destroyed. This prevents the horn sounding and also, as the vacuum switch then opens, cuts off all electric supplies. Under these conditions the brake valve will open and to prevent the brakes being applied a screw cock is fixed in the brake valve which, when screwed down, prevents the valve opening. This cock is also normally sealed open.

Principles of Operation

The various indications given to the driver are as follows:—

With distant signal clear, indicator shows "all black" and electric bell rings for 2 seconds.

With distant signal at caution, vacuum horn sounds. Driver can stop this by pressing and releasing resetting handle, which action turns indicator to show "black and yellow." If driver takes no action, a brake application starts after 2 to 3 seconds and the vacuum is destroyed in a further 15 seconds. The driver can re-set at any time after the horn has started sounding.

The electric circuit is shown in fig. 7 and as will be seen, is fairly simple.

When running between signals, the receiver armature is lying with its North contact made. Current is therefore fed to the electro pneumatic valve and also charges the 2,000 m.f. condenser which is across its coils. When the receiver passes into the S polarity magnetic flux of the permanent inductor, the receiver armature reverses, opening its N contact and closing S contact. The supply to the E.P. valve is cut off but its armature does not drop away for 1 second owing to the discharge of the 2,000 m.f. condenser. The closing of the receiver S contact picks up the South relay and current is passed through the "black" coil of the indicator.

If the distant signal is clear and the receiver reaches the North polarity magnetic flux of the now energised electro inductor within 1 second (equivalent to a speed of $1\frac{3}{4}$ m.p.h. or over), the receiver armature will be turned back to its normal position restoring current to the E.P. valve before it has dropped away. The South relay will remain energised through its stick circuit. With the receiver normal and the S relay energised, the Bell relay picks up, ringing the bell. The breaking of the back contact of the bell relay cuts the stick circuit of the S relay which drops away in its turn disconnecting the supply to the

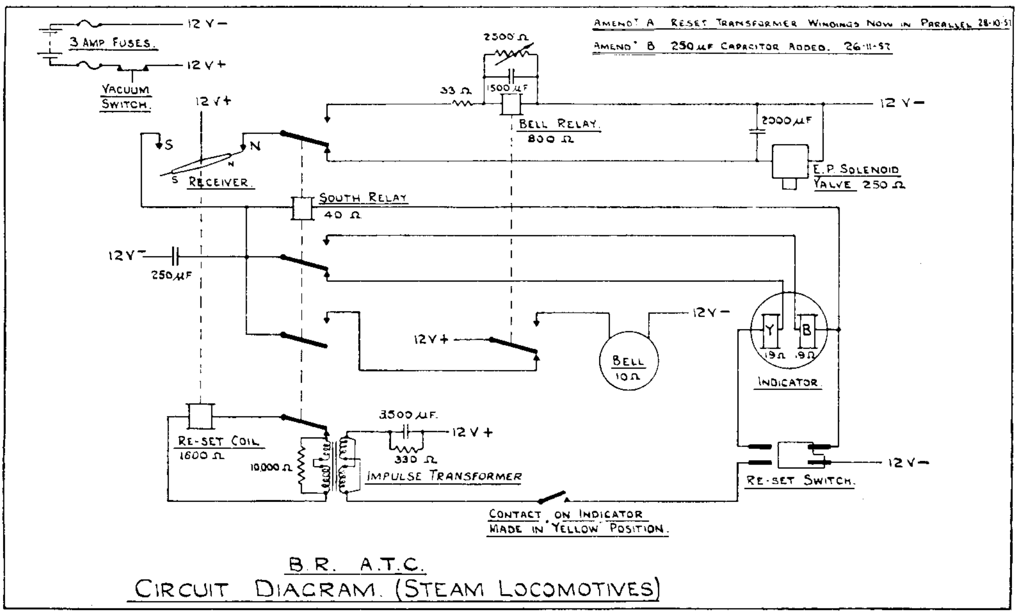

Fig. 7

bell relay. The bell relays, however, remains energised for 2 seconds due to the discharge of its 1,500 m.f. condenser. When this time is up the bell relay drops away and the circuit is restored to normal.

If the distant signal were not clear, the electro inductor would be dead and 1 second after entering the field of the permanent inductor, the E.P. solenoid would be de-energised, operating its valve to sound the horn and apply the brakes. Pressing the re-set handle on the driver's control unit disconnects the S relay which, when its armature has dropped away, puts current through the "yellow" coil of the indicator.

When the indicator has turned to yellow, a proving contact on the flag is made and current passes through the primary of the impulse transformer. This induces a high voltage impulse in the secondary which passes through the re-set coil on the receiver bottom pole piece, magnetising this in such a direction that the receiver armature is returned to its normal position. The current is cut off from the yellow coil of the indicator and restored to the solenoid of the E.P. valve to hold it in its normal position, silencing the horn and preventing or restoring any brake action. On releasing the re-set handle, the current is cut off the primary of the impulse transformer which induces a current in the secondary in the opposite direction to the first impulse, tending to operate the receiver again. To prevent this, and also to reduce the arcing at the re-set contacts, a 3,500 m.f. condenser is included in the primary circuit. When the primary circuit is made, this condenser charges up rapidly, reducing the current in the primary circuit to a few milliamperes. The induced current in the secondary is consequently far too small to operate the receiver.

This method of re-setting appears complicated but the object is to try and avoid a possible wrong side failure. If by mischance, the S contact wire in the engine receiver cable got into contact with one of the re-set coil wires, on passing a caution signal the receiver armature would make its S contact and might falsely energise the re-set coil, thereby restoring the receiver and giving the driver a clear indication. The re-set is therefore wound so that it requires a minimum of 17 volts to re-set, more than the 12 volt battery can give, and the whole object of this elaborate reset circuit is to obtain something over 17 volts from a 12 volt battery.

NOTE :—It is possible, indeed probable, that by the time this paper is read, this re-setting circuit will have been abandoned for an improved one. Its major disadvantage is that the duration of the secondary impulse is very short unless a most inconveniently large impulse transformer is used. A very high peak voltage (over 80 volts) is necessary to obtain an average of over 17. A new circuit is being tried out at present whereby the re-setting voltage will last until cut off by the receiver armature moving over so that the peak voltage need be no more than the average.

This paper is already overlong but the author appreciates that it has only touched the fringe of the subject. Descriptions have been sketchy and no mention has been made of the fitting of this type of A.T.C. to diesel or electric locomotives or multiple unit trains having vacuum or air brakes. Nor has any mention been made of maintenance requirements or servicing but if this first paper to be read on the subject arouses sufficient interest, it may be followed by others from members who in a short time will be getting first-hand experience of the equipment.

The author wishes to express his thanks to the British Transport Commission for permission to read this paper and to his colleagues, especially Mr. A. Rankin without whose knowledge and skill in design, the subject of this paper would never have been brought to its present position.

Above all, thanks must be given to Mr. J. H. Fraser whose encouragment and never failing support has helped the author over many a discouraging situation.

DISCUSSION

In throwing open the meeting for discussion of the paper, the **President** said that people were very interested in the subject at that time, inasmuch as the B.T.C. had decided to adopt the inductive pick-up instead of a mechanical pick-up, and from Mr. Currey's description, it was seen that many difficulties were encountered before the present stage of development had been reached. He thought it would be true to say that the difficulties would not have been overcome without modern development in magnetic materials and the general fact that modern permanent magnets, for example, could retain their flux for apparently an indefinite period.

He was very interested in the fact that Mr. Currey had mounted his receiver on a bogie. In association with mechanical systems, that could lead to some difficulties, and it had been the practice for many years with the system on the Western Region to mount the pick-up shoe on an axle. He presumed from the width of the air pipe—he thought that Mr. Currey had said that the normal width was 5-in.—that a vertical movement either up or down of, say, 1½-in., would not affect the equipment. Undoubtedly, the problems that had been met on steam engines would be eliminated, to a great extent, in future kinds of traction, but he had no doubt that many difficult problems would be met in fitting either electric or diesel locomotives.

Mr. G. H. Crook prefaced his remarks by warning members that his mind was somewhat prejudiced, possibly the result of circumstances. He was connected with the Great Western system of train control and his recollections went back to the 1902 period, when he first saw the system experimented with in the Telegraph Superintendent's office at Paddington. That had nothing to do with the present subject, but having been associated with that system for some fifty years or so, one did somewhat get into a rut.

Mr. Crook thought they should express their very grateful thanks to Mr. Currey for all the trouble that he had taken in writing such an excellent paper, which had resulted in a great deal of information for study.

It had been very wise of Mr. Currey not to go into the history of the automatic train control system, as it would have taken too long. The roots of the system lay a long way back in the past. Originally, the idea of transferring signals to the locomotive by means of magnetic effects went back to the Boult system, which was patented in 1893 and tried experimentally on the Great Northern Railway. Mr. Crook was in the Telegraph Superintendent's office at Paddington as a boy when Mr. Jacobs, who was then the Assistant in that office, was very busy attacking the system through the *Electrical Review*. Mr. Jacob's great point of criticism was the possibility of wrong side failures, and to that extent, he was quite right. As a matter of fact, he was attacking that system, before the

Great Western Railway system was really demonstrated.

Subsequently, Mr. Crook knew Hudd. They were together in Melbourne in the early 1920's, and from there Mr. Crook gave him an introduction to the Engineer of the Automatic Telephone Company who, in conjunction with Hudd, developed the Hudd system.

Mr. Crook did not want to say anything which would offend Mr. Currey, but after the years spent on the G.W.R. system, he was somewhat appalled at the complications introduced into the present system. No doubt, they had been forced upon the designers by means of trial and error. He was not prepared to make any detailed criticism whatever, but he did think that, in comparison with the Great Western system, it comprised too many bits and pieces, and there was a great complexity in some of the apparatus on the locomotive, which Mr. Currey had appreciated and admitted.

With regard to the indicator that was shown, much emphasis had been placed on it, presumably as a safety device. In the original G.W. arrangement, there was an indicator showing danger, and in the early years, between 1905 and 1910, it was deliberately eliminated, in conjunction with, and with the approval of, the then Board of Trade. Personally, Mr. Crook had no time for this indicator, because from what he had seen and heard at enquiries into accidents and irregularities, it was always found that, when such an irregularity occurred, the driver was always having his attention, or claimed to have his attention, directed to something else. Mr. Crook did not think the indicator was worth the expense. He was biased in what he was saying and it was purely his personal view.

He did not agree with the position which had been tentatively decided for the inductor—that was, 200 yards before reaching a signal. His experience with the G.W. system was that difficulties in interpretation occurred through signals obtained at ramps for signalling positions which were not at a signal itself. His own opinion, after many years in connection with these systems, was that the signalling point should be at the signal itself.

He had not had time to study the paper thoroughly, as it demanded, but he thought it full of interest, and he could only hope that, in prosecuting this work, Mr. Currey and the British Railways would come to a satisfactory conclusion.

In replying, **Mr. Currey** thought there was only one real question to answer, and that was with regard to the position of the inductors. He could not agree that they should be placed at the signals; his view of the function of automatic train control was to give the driver a chance of observing the real signal in bad weather If the inductor was placed at a signal, when travelling at fairly high speed, by the time the driver had heard the warning, registered it and had had a look out, he would be past the signal Two hundreds yards, he thought, was the absolute minimum at which the inductors should be placed, to give the driver a chance of observing the signal. If they were going to higher speeds, the inductor would have to be moved even farther out, to give the driver that chance.

With regard to the indicator, the driver was not expected to look at it continuously. It was there as a safeguard only, in case the driver had got into a mechanical state, after several hours on the road, and suddenly wondered whether a signal he had passed was a caution or a clear. He then looked at the indicator, which showed him at a glance. It was not visual cab signalling. Visual cab signalling did intend that the driver should look at the indicator continuously, In the system described by Mr. Currey, the indicator was only there in case it was wanted. It was better for a driver to take his eye off the road to look at the indicator, rather than make a guess, and possibly a bad guess.

Mr. R. A. Green said that he was disappointed in one respect, and that was, in the title of the paper. In view of the enormous amount of misunderstanding, chiefly in the mind of the public, on what was A.T.C., he thought that the opportunity should be taken to stress that it was a warning control and, in no sense, a train-stop. Therefore, a better title for the paper and name for the system would be " An Automatic Warning Control System," and he would like to know whether it was the intention, before the scheme was formally launched, to change the title.

Mr. Green enquired what were the considerations which led to the adoption of the electric pick-up from the receiver and not a direct vacuum from the receiver?

There were various sighting requirements, and looking for a Distant signal with A.T.C., operating from a mere 200 yards in advance of it, he wondered why the braking had not been arranged in the form of emergency braking. He thought it was solely the normal service application, but one must accept the fact if A.T.C. was allowed to take control, that was, if the driver had not cancelled the warning, that it was an emergency. Was the leisurely application of the brakes in the normal service manner the right thing to do?

Mr. Currey replied that it would be appreciated that he did not select the words " Automatic Train Control." They were rather old by this time, though an attempt was once made to change the name to " Automatic Warning Control." Personally, he was not in favour of it, as it seemed to be contradictory—it was not exactly a warning control.

Regarding the electrical or vacuum system from the receiver, it had to be the electrical system, in general, because of the demand made that it must have a bell as a clear signal, rather than a horn.

He quite agreed that one could obtain an emergency brake. The choice of the service application was dictated by the necessity of running non-fitted freight trains; it would be impossible to put an emergency brake on those, when running at a low speed. After all, the Distant signal was supposed to be a service application from the stop signal, and so they had tried to give that same distance and the same braking application, as far as it could be done automatically, without too many complications.

Mr. Hall, referring to the apparatus shown in the diagram for steam locomotives, asked whether Mr. Currey could give some idea of what was envisaged for diesel and electric locomotives.

Replying, Mr. Currey said that the one common feature was the receiver which was common to all types of stock.

On diesel locomotives hauling vacuum fitted stock, it was not necessary to economise in battery power, as on steam locomotives; they had the type of battery which was charged on the locomotive when running, so they could afford to be a little more generous. They could take away from the driver all those parts which were of no interest to him. The electro-pneumatic valve had been taken out and put elsewhere, the driver being left merely with an indicator and a re-setting handle. A press button or plunger was used for that purpose. With one plunge, re-setting took place automatically. With diesel locomotives, there was more power and they had been able to improve the circuit. As far as the apparatus was concerned, it was not necessary to have such robust material as on steam locomotives; it was not necessary to seal off against steam and sulphur fumes or heat.

There was no difference between an electric locomotive hauling vacuum stock and a diesel locomotive, but with air brake multiple-unit stock, the very characteristics of the air brake had meant a complete re-design of the braking system, and this was only in its infancy.

Mr. R. J. Post asked whether the use of copper clad insulated cable for locomotives had been considered? And if it had, the reason for rejecting it?

Mr. Currey answered that it had been considered and rejected, the biggest trouble being that the locomotive shop fitters could not distinguish it from ordinary tube. They used to drop it, and this was not good for the wire. After trials, they preferred to use a P.C.P. cable, which stood up to test in a remarkable fashion.

Mr. M. E. Leach said that fitting inductors to concrete sleepers seemed to pose quite a problem. Similar trouble had been found with another system. Could Mr. Currey say how he proposed to fit A.T.C. inductors to concrete sleepers? Presumably the sleepers would not have holes already in them for fixing plates and bolts.

With regard to the power supply for the electro-inductors, had consideration been given to the use of polarised relays in the block circuit, rather than going to the expense of installing approach track circuits?

Reference had been made to the energisation of the inductor relay through an arm contact. The figure quoted was 25° to 30° and he wondered whether that was perhaps a little low and might, at night time, result in a clear signal being given on the indicator, whereas a yellow light showed in the signal, because it had not come off far enough. It had been found necessary to go to 40° or more to avoid misleading double indications.

Regarding the circuit, would Mr. Currey

give some details of the type of relay used, as it had been stated that, with Post Office relays, vibration troubles had made them unsuitable.

Could Mr. Currey say whether there had been any experience, in connection with the inductor contacts, of any metal transfer as the result of incorporating a capacitor?

In the beginning of the paper mention was made that a certain pressure drop was necessary to operate the siren and that pressure drop prevented sufficient air from entering the train pipe to overcome the ejector, as a result of which, it was decided to fit a balanced brake valve, as used with Hudd system. Mr. Leach said that there was a way of preventing that, by fitting an isolating element in the system, to isolate the train pipe from the small ejector. If the passenger communication cord was pulled and there was a drop in the train pipe vacuum, the train pipe was isolated completely. That had been found quite satisfactory, ensuring that there was a suitable brake application.

In reply, Mr. Currey said that special concrete sleeper fittings had to be provided where it was necessary to fit the inductors, and the designers had, so far, had a great deal of trouble. A re-design had to be carried out at very short notice, when the civil engineer flatly declined to provide timber sleepers when it was required to fit both ends of the electro-inductor, both ends of the permanent inductor, and three supports for the ramp, all on one sleeper with a common set of holes. Now, they had five cored holes in the centre of the concrete sleeper. Of course, concrete sleepers themselves varied enormously, both in height from the top of the sleeper in the centre of the 4-ft. to rail level and also in the width. It had been necessary to design brackets, which the civil engineer would provide, to bring the level up to that of the ordinary timber sleeper.

Regarding the energisation of inductors by polarised relays in the block circuit, he had not thought of doing that in this case, although it had been done in the past with I.B. signals. He did not see why it should not be used. The B.T.C. had not, in fact, contrived a " best method " of energising inductors; each Region had their own signalling methods and it was left to them to adopt what they thought suitable in any specific case.

With regard to the arm contact, Mr. Currey said that he ought to have said that 35 ° was for upper quadrant signals, not for lower quadrants.

They had modified the Post Office type of relay. The trouble with the Post Office 3000 relays was that the coil was over-size and used to come loose. The relay itself had only a small end fixing and there was trouble with that breaking up; also there was trouble with the armature jumping about, even though double screws were used. The armature was now suspended on a strip of belryllium copper and the whole relay had been put into a box, the fixing being on the base, instead of on the end. Those relays were proving satisfactory and were giving no trouble. Most of them, up to the present, had been used on the diesel locomotives, though there were some on the steam stock.

No trouble had been experienced with metal transfer on contacts. A large condenser across the E.P. valve had been in use, and although trouble might have been expected with it, in actual fact there had been no trouble at all from that source. The contacts were made of fine silver; they had settled on that for all apparatus, except for the south relay, which was the only commercially produced relay used that had platinum contacts.

With regard to the isolating of the train pipe from the ejector, there was one disadvantage in using that—once it had gone off, there had to be some means of restoring it. One had to apply the brakes or balance out something to restore. In other words, if the brake was applied, the driver had to re-set the A.T.C. and balance out to restore that valve, which had been used for another purpose—for the communication cord. The communication cord was not allowed to be cancelled, so was admirable for that purpose, and whilst there was no objection to it for use with A.T.C., there were distinct advantages in the balanced brake valve, when it was considered how very cheap it was, compared with the system as a whole.

Mr. A. N. McKillop asked to what extent the author had drawn upon experience in European countries of A.T.C. for the design of the system described in the paper.

It seemed to him that a great deal of trouble had been taken to make the working of the apparatus reliable, but he was rather dubious about the electrolytic condensers. Did Mr. Currey think they would be completely reliable in service?

Mr. Currey explained that he had not drawn on European experience. The fact was that they had a very tight remit, when they first started on the job, and the general use and type of equipment in Europe did not meet one single part of that remit, so they had to start on their own. To a very large extent, two other systems had been found very suitable so it was quite reasonable that they should more or less follow on the same lines.

Modern electrolytic condensers, used under proper conditions, were extremely reliable. Electrolytic condensers, as we use them, should not be confused with the television use of them, where they are put in the hottest part of the set. Mr. Currey said that the condensers they used were put in the coolest part possible, and in five years, they had had only one failure.

Mr. W. H. Challis said that, if he had read the paper correctly, the south relay had been energised to put the brakes on. If this was so, was the author satisfied with such a circuit, which appeared to offend all principles of signalling, in that it required current to put the brakes on? Should not a failure of current stop the train, rather than let it go?

Mr. Currey explained that although the contact of the south relay was in the circuit, that contact was only there as an isolating contact to prevent the discharge of the condenser across the e.p. valve. The main feed for the e.p. valve came through the receiver itself as soon as the current was cut off from the e.p. valve.

Mr. A. Moss that as a former colleague on the Eastern Region, he had been a "guinea pig" on the installation side with regard to the apparatus. Originally, he bought the Hudd magnets up in Scotland and put them in on the line between Edinburgh and Glasgow. When the war came, the scheme was dropped. On leaving Scotland, Mr. Moss thought that he had left the case for good, but the question of A.T.C. came back. The Hudd magnets would not stand up to heavy traffic; they were satisfactory on the Tilbury Line, because the speed there did not exceed 40 m.p.h. With speeds of 70 m.p.h. or 80 m.p.h., trouble was experienced, and he was delighted when he heard that the magnets had been re-designed.

On the Tilbury Line, he thought that originally the Distant arm was included in the electro-magnetic circuit. Then it was taken out and he hoped that in the next installation it would not be necessary to fit an arm circuit at all, being content with a lever; but senior power ruled otherwise, and the arm circuit had to be included. As to the 25° to 30° already referred to, human nature being what it was, the signalman gave lazy pulls and the driver's interpretation as to whether the arm was "on" or "off" made it very difficult to arrive at a correct angle to suit the signal engineer and avoid having a failure. Finally, Mr. Moss was forced to reduce to $27\frac{1}{2}$°, as low as he dared go. He believed that, at the time he retired, satisfactory results had been obtained, allowing the apparatus to function without so many complaints from drivers that they were getting different indications from those shown by the arm.

Mr. Hounsom enquired whether any modification was needed in A.T.C. apparatus where third rail electrification existed.

Mr. Currey replied that, at the time, a good deal of trouble was being experienced—a good deal of it theoretical trouble, fortunately—with magnetic fields due to third rail electrification. Quite frankly, he thought he could see the answer to it, but it was not an answer he was prepared to supply at the moment.

Mr. J. H. Fraser remarked that the only thing standardised about the B.R. system was field strength and indications. Other circuitry could be used so long as it gave the same indications in the cable and the same field strength.

Colonel Woodhouse, referring to the current consumption of suppressors that were needed to nullify the effect of the permanent magnet on a single line, asked whether it was now the policy to suppress A.T.C. indications at a Distant signal with stop arm alone or a red colour light signal? Or had that been altered?

Mr. Currey stated that the policy of suppression at red signals, colour light or semaphore stop and distant, had been dropped. Now, a caution signal was always given at a Distant, if it was anything else but green.

Mr. T. Holland was particularly interested in the experimental re-set circuit involving transistors and wished to know what frequency was being used.

Mr. Currey replied that the frequency being used at the moment was between 600 and 800.

Mr. Pope wished to know whether there had been any trouble with what must be the most delicate part of the apparatus, the receiver bearings. Any watch was subject to any vibration on bearings.

Mr. Currey replied that they were nothing like watch bearings. They were round about 5/32-in. diameter and were a trunnion bearing. The trunnions were of stainless steel and the magnet armature itself was moulded in nylon.

Mr. D. L. Mitchell referred to the screwing down of a plug to put the apparatus out of use, in the event of a failure, and asked what was the safeguard against the plug being screwed down, when it should not be.

Mr. Currey said that the only safeguard was that the plug was sealed open with a wire and lead seal, in the same way that the isolating cock in the vacuum supply was normally sealed open. The shed fitters had to examine and mark that the seal was intact before the journey out. A driver taking over a train was supposed to examine it and see that he was taking over with the seal intact.

Mr. Edwin believed that it was the practice for the lever contact to be taken through the signal arm to the line relay; and if the line relay failed, there would be a wrong indication. It did not depend upon the position of the actual lever signal arm. On another system, the circuit was taken from the lever contact to the relay and then a second circuit through the relay contacts and the arm, so that both relay and arm had to be in correspondence before a clear indication.

Mr. Currey said that he would have liked to have adopted that himself, but unfortunately the current was heavy and it was not possible to take the line wire up a signal through the signal contact, as it would mean the loss of a good deal of magnetic flux at the inductor. That was why they were forced to ensure that the relay controlling it had returned to its normal de-energised position.

Mr. Smalldon asked whether individual testing had to be carried out when a multiple-unit train was split up.

Mr. Currey answered that such individual testing was not possible.

A very cordial vote of thanks was proposed by the **President** to Mr. Currey for his excellent paper. This was carried with acclamation.